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AGRICULTURAL MEMORANDUM NO 355
CEREAL MILDEW - WEATHER CRITERIA FOR INFECTION OF THE HOST

by C V Smith

0107253

1. INTRODUCTION

By general agreement, the life cycle of the cereal mildew Erysiphe graminis is sensitive to environmental factors. Yarwood (1970) has given a comprehensive review of various facts and opinions on this matter.

Ag Mem 323 - "Some notes on the attempt to find relationships between weather and mildew percentage in Proctor spring barley" examined associations between percentage of mildew (as observed at growth stage 10.54) and monthly mean weather parameters over the growing season, at 4 stations and for a 10 year sample period. No definite relationships could be found.

Earlier a similar (but unpublished) result had been obtained by C V Smith at Meteorological Office, Cambridge again using data supplied by Dr Doling of NIAB. Indeed, it was with this study in mind that the suggestion was made in Ag Mem 278 that "to develop criteria for successful and plentiful host penetration requires examination in detail of weather factors other than temperature and over periods of time less than a day". All that was being put forward here was that the scale and frequency of biological and meteorological observations should bear some sensible relationship to the rate at which critical physical and biological processes apparently take place.

2. CURRENT DATA

In 1970 NAAS organised cereal mildew counts at a number of sites at approximately fortnightly intervals throughout the growing season. The most convenient meteorological data were taken to be those of the agro-met (crop-weather) stations. Basically these provide a single, full observation at 0900 GMT of the current weather, together with data which give some idea of the weather during the day (maximum/minimum temperatures, rainfall amount, sunshine hours). At one site, these observations were supplemented by a "wetness" recorder.

3. THE PROBLEM

Implicit here were the assumptions that the detailed environment around the leaf was important, that a few hours of a particular type of weather could be critical, and that on-site weather data should be used wherever possible. If minimum temperatures were in any way relevant, for example, then minimum temperatures, as with frost, would reflect the local meso-climate, and weather observations made even a few miles away, would not necessarily be strictly applicable to the crop under observation.

The problem was seen as the identification of individual days, the weather of which led to substantial infection, as evidenced by the subsequent rapid

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and exponential increase of mildew counts. The work of Last indicates the period of incubation, after penetration of the host, to be a function of temperature. In general, we may expect a time lag of the order 3-6 days before inoculation results in visible pustules (on which the count is made). It was assumed that the days identified as suitable for infection, after the first of the season, would obviously assist the observed progress of the disease, but were not strictly essential to the continued spread of the disease.

The single daily observation of the crop weather station may provide up to 20 or more values of largely independent environmental parameters. The requirement was to select combinations of these parameters which fitted the cereal mildew progress curves from different sites and at different times.

This is perhaps a convenient point to mention some of the uncertainties of the biological observations. They were made not more frequently than at fortnightly intervals, so that the take-off point for the mildew progress curve is not a precisely defined point in time from these data. There is a sampling error in the mildew count. I have no figures for this, but it is likely to be large. The mildew amount is expressed as a percentage of leaf area for a given leaf number. There are 2 difficulties here. On the one hand there is the interpretation to be placed on the mildew count as a given leaf dies back (for one of several possible reasons); on the other, the leaf number assigned is a function of growth stage - leaf 1 always being that at the top of the plant - and leaf number is not fixed until growth stage 8+. There is some evidence of variation in varietal resistance to disease and possibly that growth stage and even manurial treatment (ie rate of growth) may influence susceptibility.

Finally of course, for inoculation to take place, spores must be present in the atmosphere or on the plant and reach the leaf surface during the critical weather period. In this analysis, no use of any information on spore counts has been made. It is known however that spore release is a function of weather - agitation of infected leaves by wind leads to an increase in spore numbers over a crop. The spores are also scavenged and removed from the air by rain, which incidentally inhibits sporulation. We have had to assume that overwintering foci provide a persistent, background level of inoculum.

4. SUGGESTED CRITERIA FOR INFECTION DAYS

Days suggested as suitable for infection have the weather characteristics summarized in the nomogram attached together with the following supplementary criteria.

Over the 24 hour period following the 0900 GMT observation (to which the nomogram applies)

(i) the daily rainfall $\leq$ 0.04 inches
(ii) the daily sunshine $\leq$ 8.5 hours

The nomogram implies

(1) The dew point T_D at 0900 GMT $\geq$ 52°F
A dew point $\geq$ 60°F is treated as 60°F

Since the air is not normally saturated, the air temperature at 0900 GMT will generally be several degrees higher than T_D.

(2) The grass minimum temperature is indicated as T_G. Lines of $(T_D - T_G)$ are shown on the nomogram. There are no restrictions on the permitted value of T_D in the evaluation of $(T_D - T_G)$, other than that $T_D \geq 52^\circ F$.

Values of $(T_D - T_G) > 10$ deg F are treated as $(T_D - T_G) = 10$ deg F.

The assumption is that the gross minimum temperature T_G approximates to the minimum temperature measured near or on the leaves exposed at the top of the crop. If the leaf surface temperature falls below the dew point of the air, then condensation will occur on the leaves. The magnitude of the quantity $(T_D - T_G)$ gives some broad measure of the duration of surface wetness, though the surface wetness recorder installed suggested there is no simple, one-to-one relationship between $(T_D - T_G)$ and the period of wetness.

(3) To arrive at the minimum acceptable value of the relative humidity observed at 0900 GMT for the day to be regarded as an infection day, proceed as indicated by the dotted lines on the nomogram, ie horizontally from the T_D value until an intercept is made with the appropriate isopleth of $(T_D - T_G)$. Proceed vertically down from this intercept to the relative humidity axis.

In the example shown, the 0900 GMT dew point of $55^\circ F$ is associated with a value of $(T_D - T_G) = 6$ deg F and gives a requirement for the 0900 GMT relative humidity to be at least 91% before we have an infection day.

Physically, we might regard the humidity and sunshine criteria as relating to the rate at which the leaves dry.

5. RESULTS

Rather than attempting to summarise these in tables or graphs, it was felt that discussion might best be served if infection days were simply located on the mildew progress curves supplied by the plant pathologists.

Where no infection days are shown, the criteria are not met.

No significance attaches to an infection day shown above the time axis of the progress curves. It would have been placed in this position simply to avoid obliterating a date marker.

Fig 1 Wye (Zephyr) - no comment.

Fig 2 Whitchurch - Long Sutton met data. The sites of the biological and meteorological observations are several miles apart.

Fig 3 Belbroughton - sites several miles apart. One might have been happier if subsequent infection days could have been shown after 20 June.

Fig 4 Wellesbourne - like Belbroughton is in the West Midland region. It shows a more uniform distribution of infection days. Figs 3 and 4 show the local nature of the criteria for infection.

Fig 5 Rothamsted - no comment.

Fig 6 Tytherington - sites several miles apart.

Fig 7 Tockington - sites several miles apart. The infection day in late May is at a very early growth stage and is presumably scarcely relevant to later mildew counts (on leaves which did not exist in late May). All we know is that a large increase in mildew took place between the 10 and 16 June. An infection day on the 11 is not necessarily late or inconsistent.

Fig 8 Boxworth (Julia) - the growth stage at the beginning of June does not necessarily provide the leaves on which counts are made subsequently.

Fig 8a Snaith - sites several miles apart. The growth stage (4+) for the first infection day does not necessarily provide the leaves on which first significant mildew is observed on 5 June.

Fig 9 Thornbury - sites several miles apart.

Fig 10 Aberporth (Proctor) - no comment.

Fig 11 Chalgrove - sites several miles apart.
Infection days identified are late.

Fig 12 Wye (Julia) - smoothing of the progress curve for leaf 3 might lead one to suppose that the infection day criteria are adequate.

Fig 13 High Mowthorpe - we have an increase in mildew between counts made on the 3 and 17 June. A first infection day on June 8 is not necessarily late.

Fig 14 Newport - we have an increase in mildew between counts made on the 4 and 24 June. A first infection day on June 12 is not necessarily late.

Fig 15 Gleadthorpe - we have an increase in mildew between counts made on the 1 and 18 June. A first infection day on June 11 is not necessarily late.

Fig 16 Tong - sites are several miles apart. The first infection day is perhaps a few days later than one could have wished for.

Fig 16a Osgathorpe - sites were several miles apart. The first infection date shown is late by a few days.

Fig 17 Aberporth (Sultan) - this variety was resistant in 1970.

Fig 18 Winchester - sites several miles apart. In view of the other progress curves shown, one must suspect that factors other than weather favourable to mildew spread were dominant.

Fig 19 Boxworth (Proctor) - comparison of the progress curves of Figs 8 and 19 suggests that factors other than weather favourable to mildew spread were dominant.

6. DISCUSSION

The only sensible way to sift the mass of weather data available, and the possible combinations of daily weather parameters applicable to different sites and different times, was through the construction of models of likely weather sequences which might be relevant. This is an iterative process, which attempts to obtain the maximum internal consistency among the data being examined. There was no single simpler sequence that fitted without modification.

Whether or not the sequence of events suggested here, fit in with the preconceived ideas of others (on the weather necessary for the spread of mildew), the only real question is do they provide a working guide to identify the take-off point of the cereal mildew progress curves?

The criteria developed from the 1970 season data have been applied to such information as was available from the NAAS regions in 1969 and to Rothamsted data for 1968. The results are comparable with the progress curves shown for 1970.

If these criteria are acceptable, the way would seem open to carry out a simulation study on the effects of spraying at different infection dates, growth stages, calendar dates, other suggested infection criteria etc.

The economic results of such a study could be considerable. One is reluctant to use the "Gee-whiz" statistic, but one accepted estimate is that cereal yield is reduced by

$$2.5 \sqrt{\%\ \text{cereal mildew}}$$

The maximum annual saving by judicious spraying, using some such criteria as those proposed here, would be of the order 3 million tons (ie 25% of the annual cereal crop) and worth perhaps £90 millions a year.

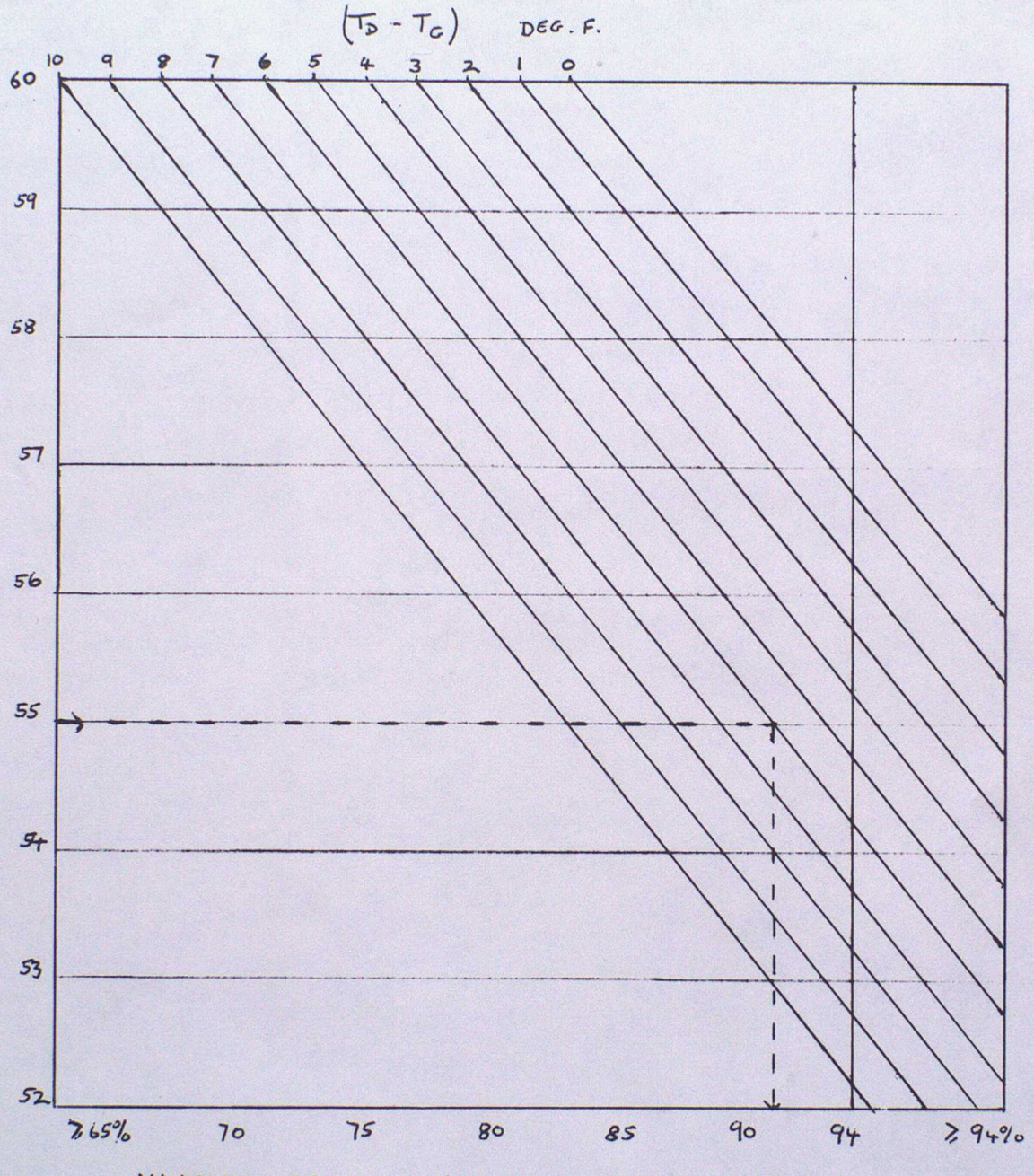
Meteorological Office
Cambridge

January 1971

References Hill SA 1970 - unpublished paper available at MAFF Bristol

Last, F T 1963 - Effect of temperature on cereal powdery mildew. Plant Path (12) pp 132-133

IDENTIFICATION OF BARLEY MILDEW INFECTION DAYS



T_G = GRASS MINIMUM TEMPERATURE -DEG. F.

ADDITIONAL RESTRICTIONS

(i) $T_D > 60°F \equiv 60°F$ IN DECIDING GRAPH ORDINATE.

(ii) $T_D - T_G > 10°F \equiv 10°F$ IN DECIDING GRAPH ABSCISSA

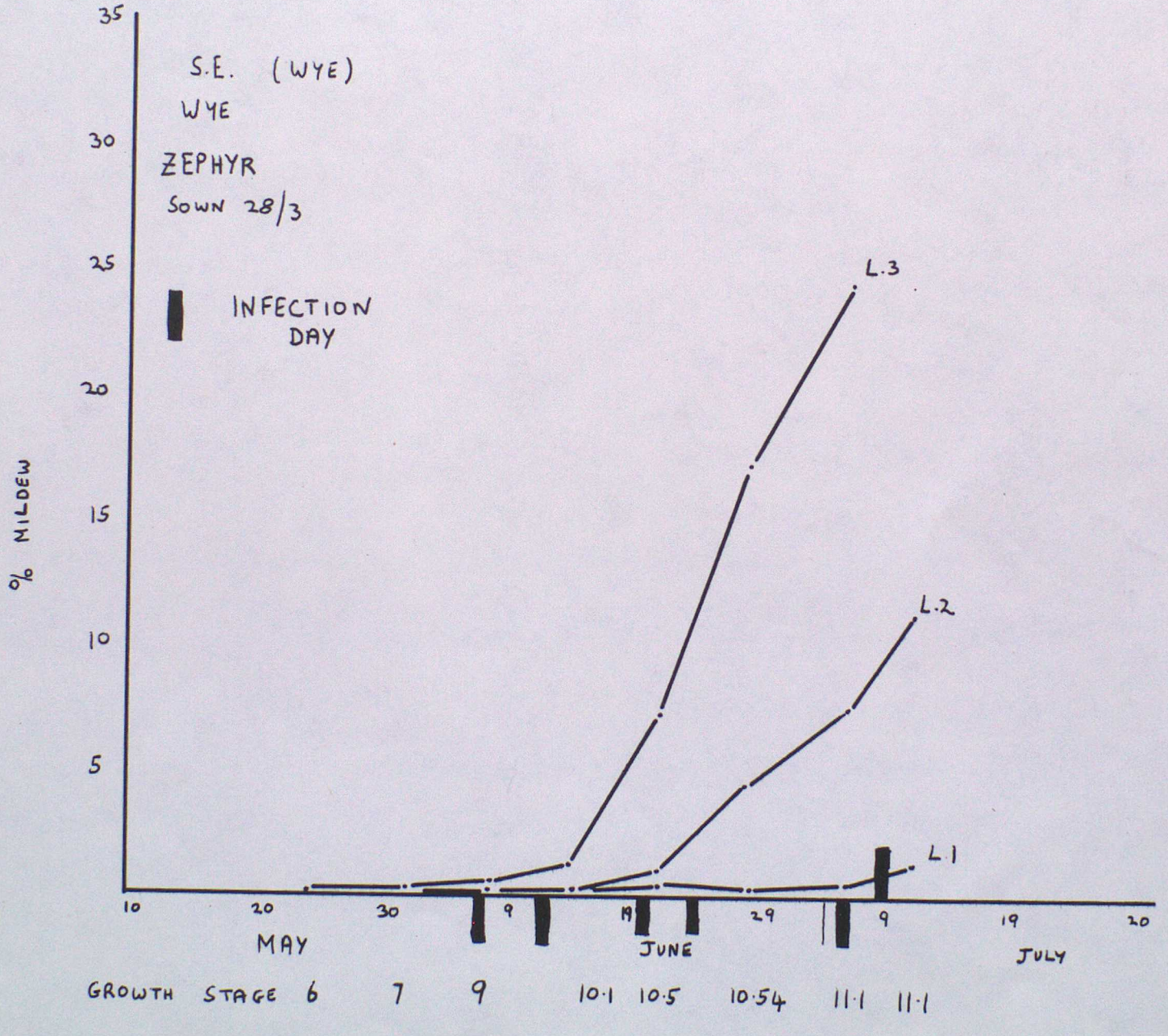
(N.B. THERE ARE NO RESTRICTIONS ON PERMITTED VALUE OF T_D IN THE CALCULATION OF $T_D - T_G$)

(iii) DAILY RAINFALL $\leq$ 0·04 INCHES

(iv) DAILY SUNSHINE $\leq$ 8·5 HOURS

BARLEY MILDEW PROGRESS CURVES

1970



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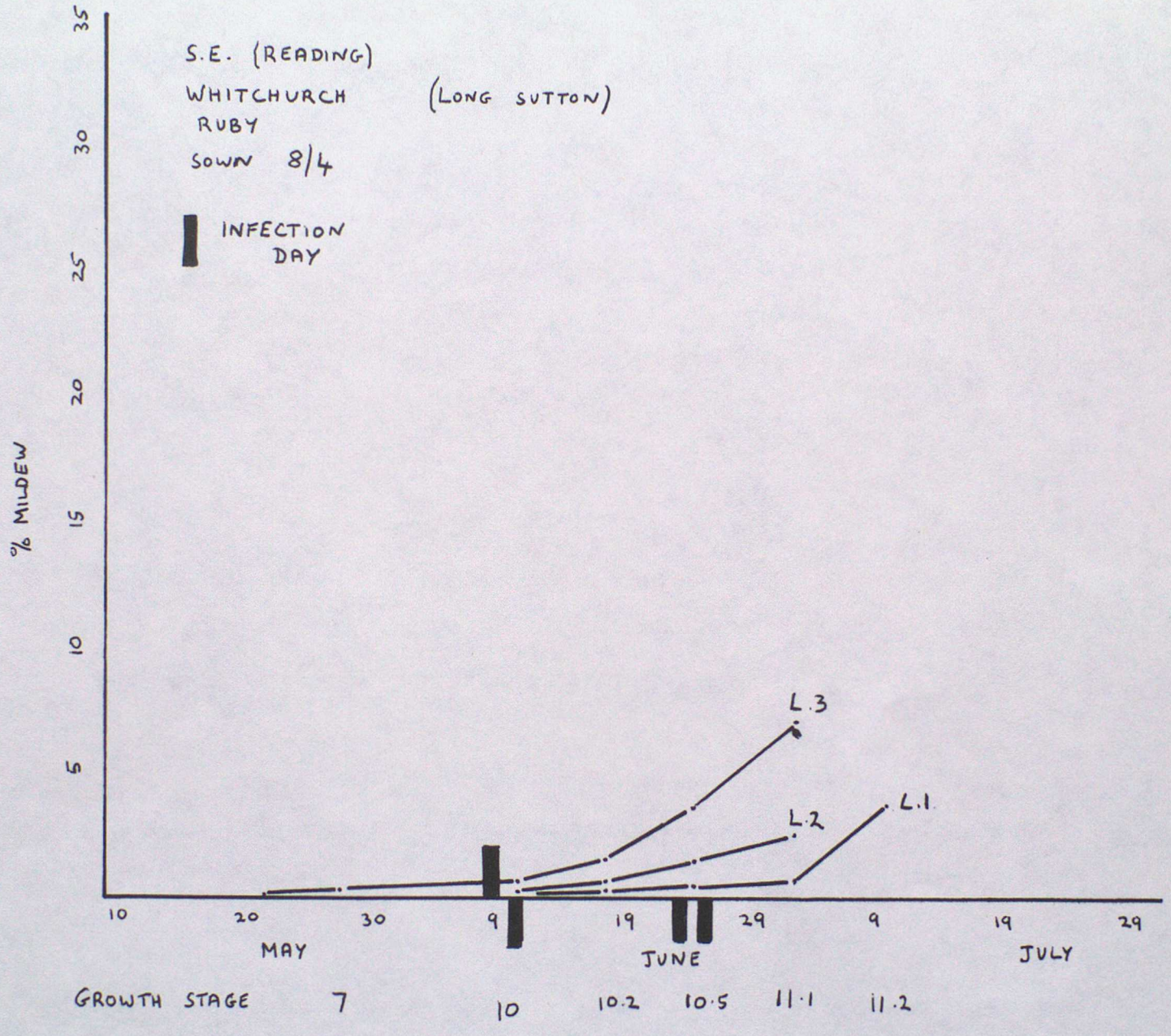

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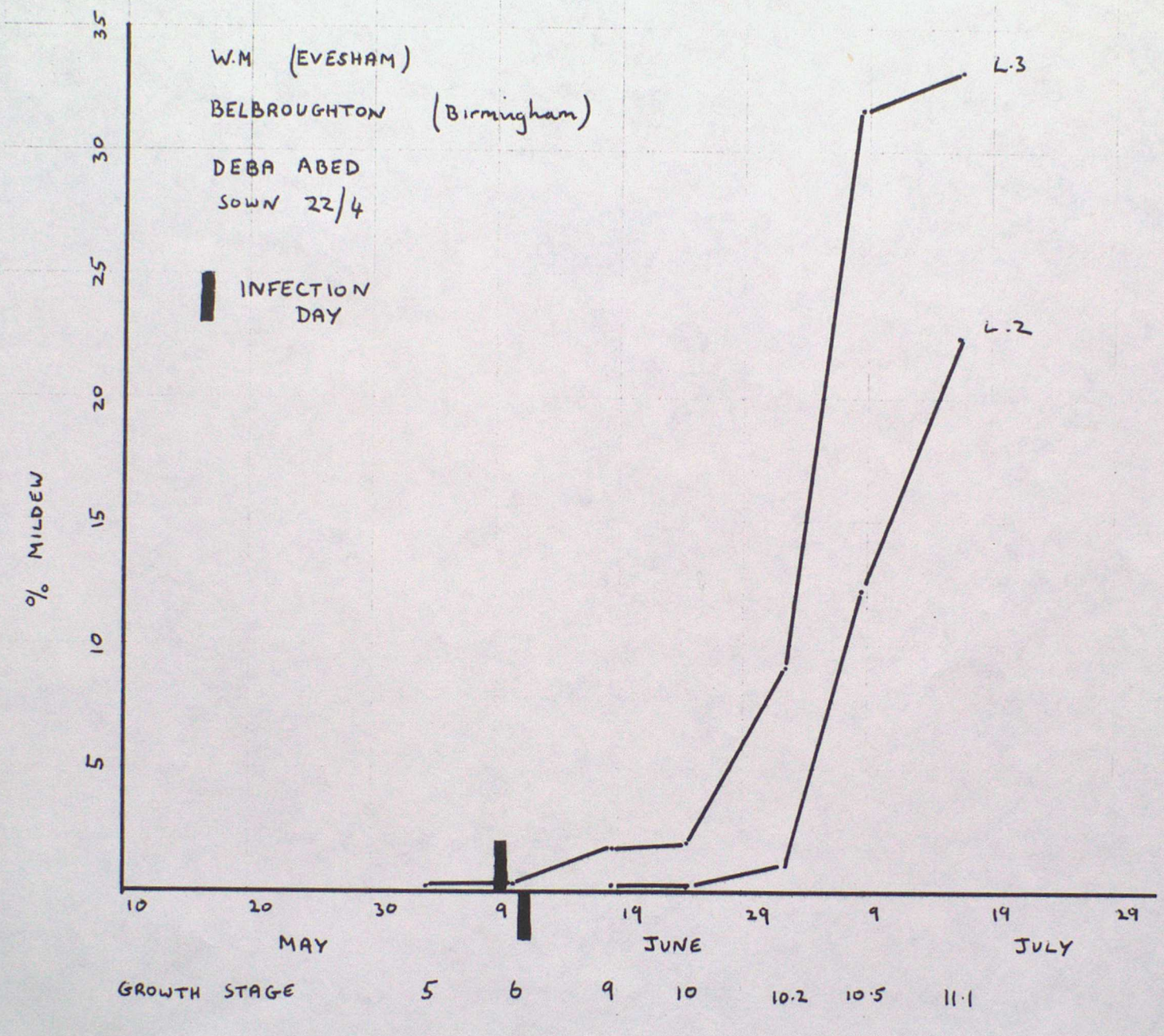

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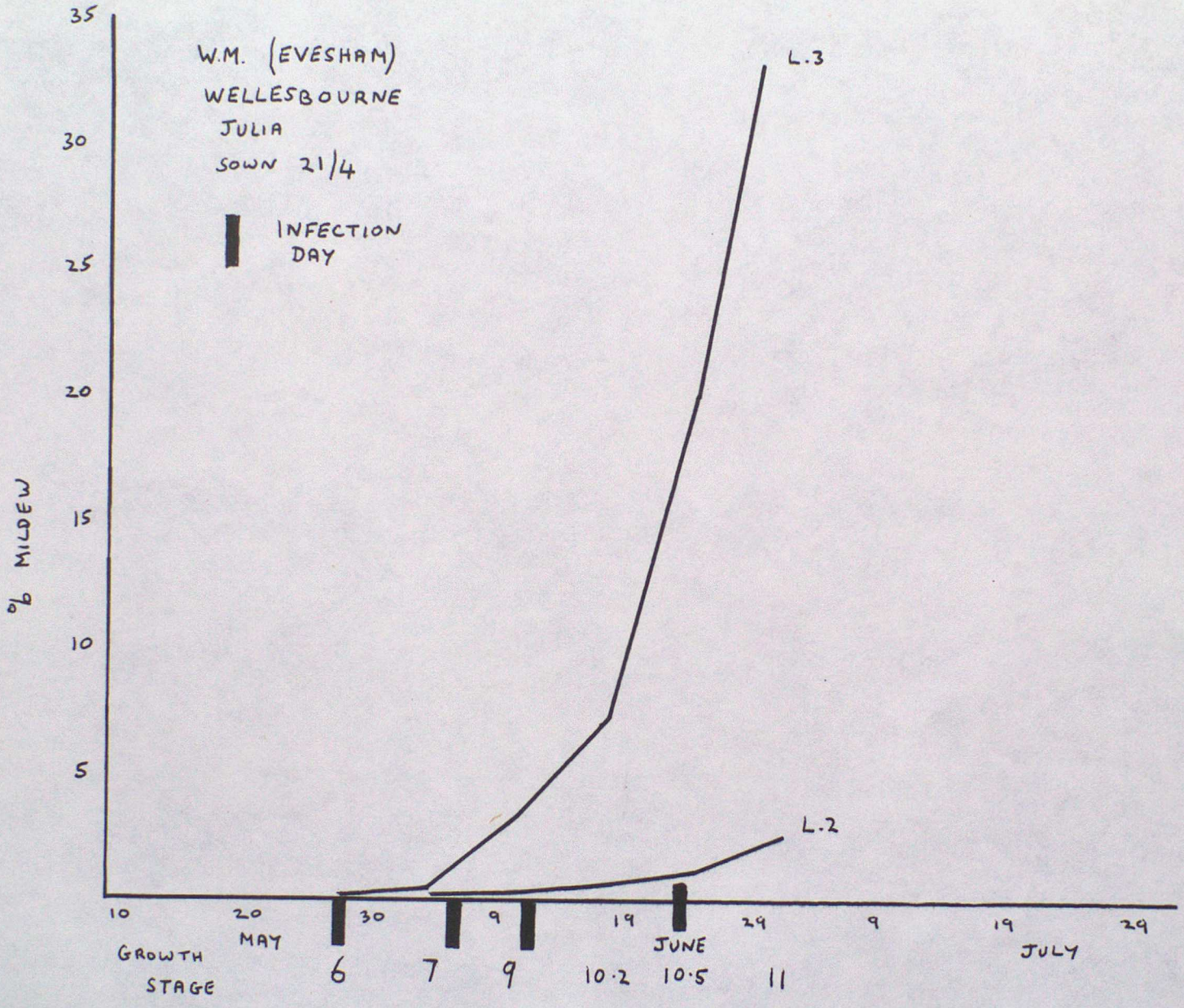

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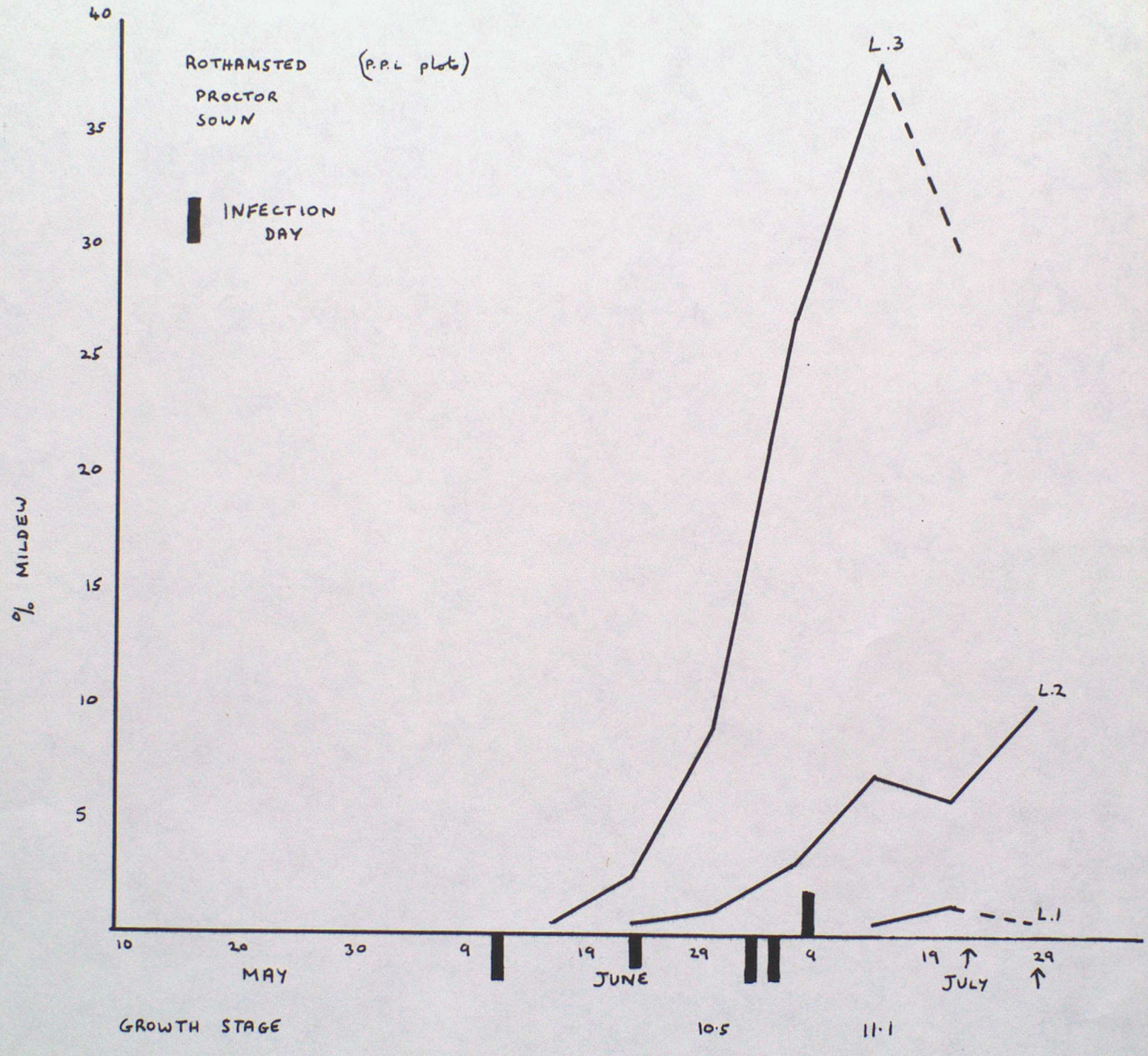

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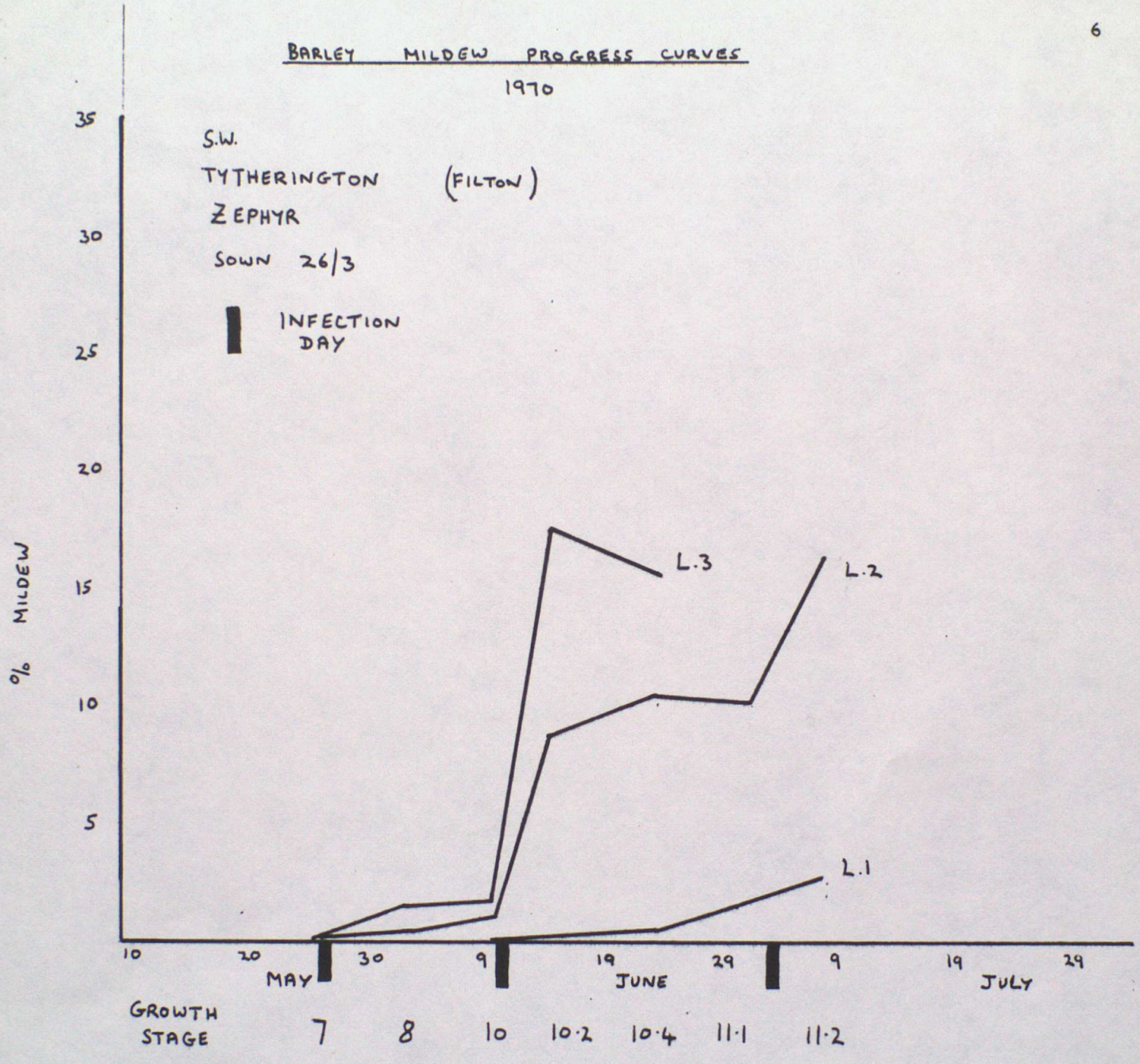

BARLEY MILDEW PROGRESS CURVE

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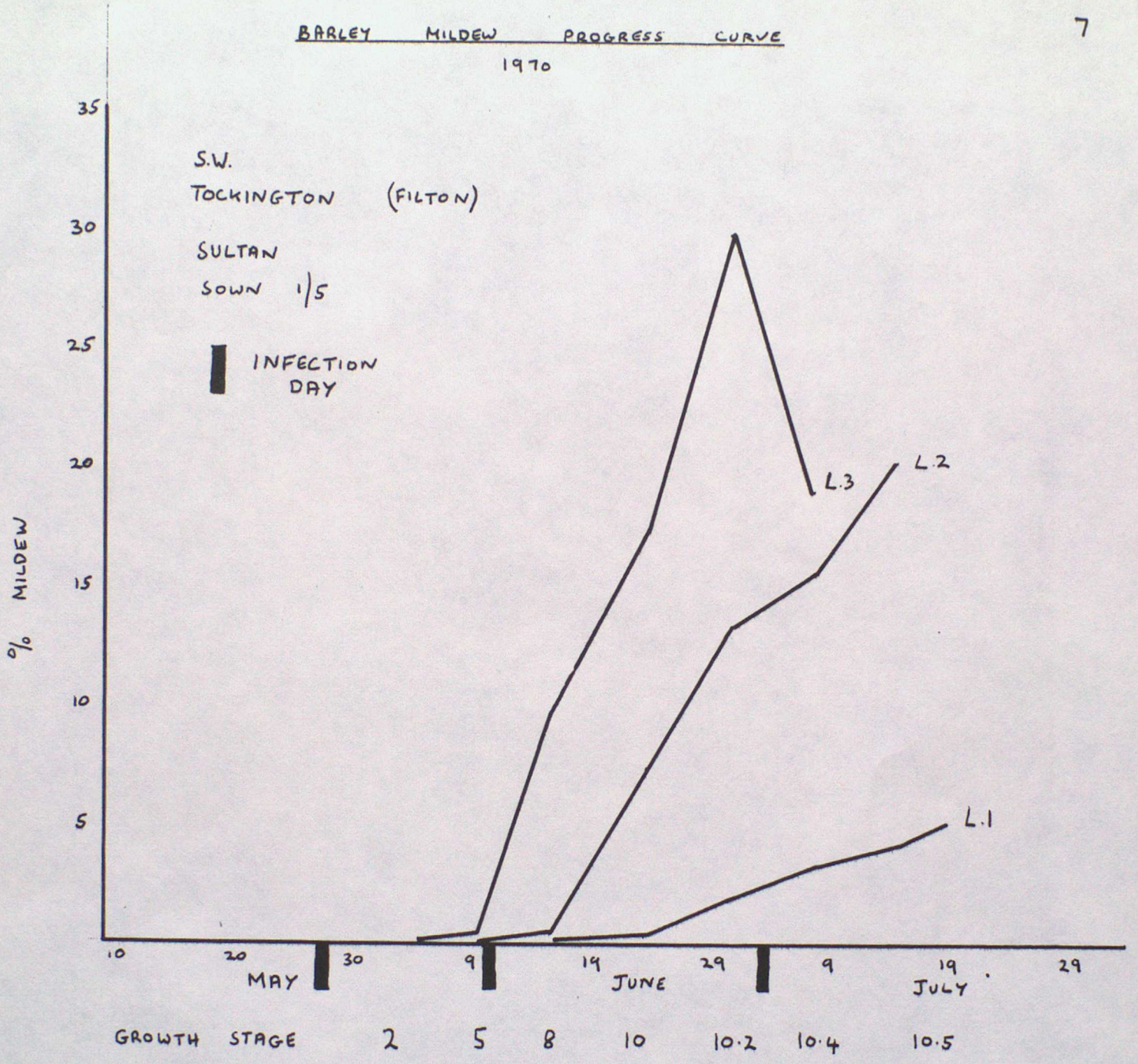

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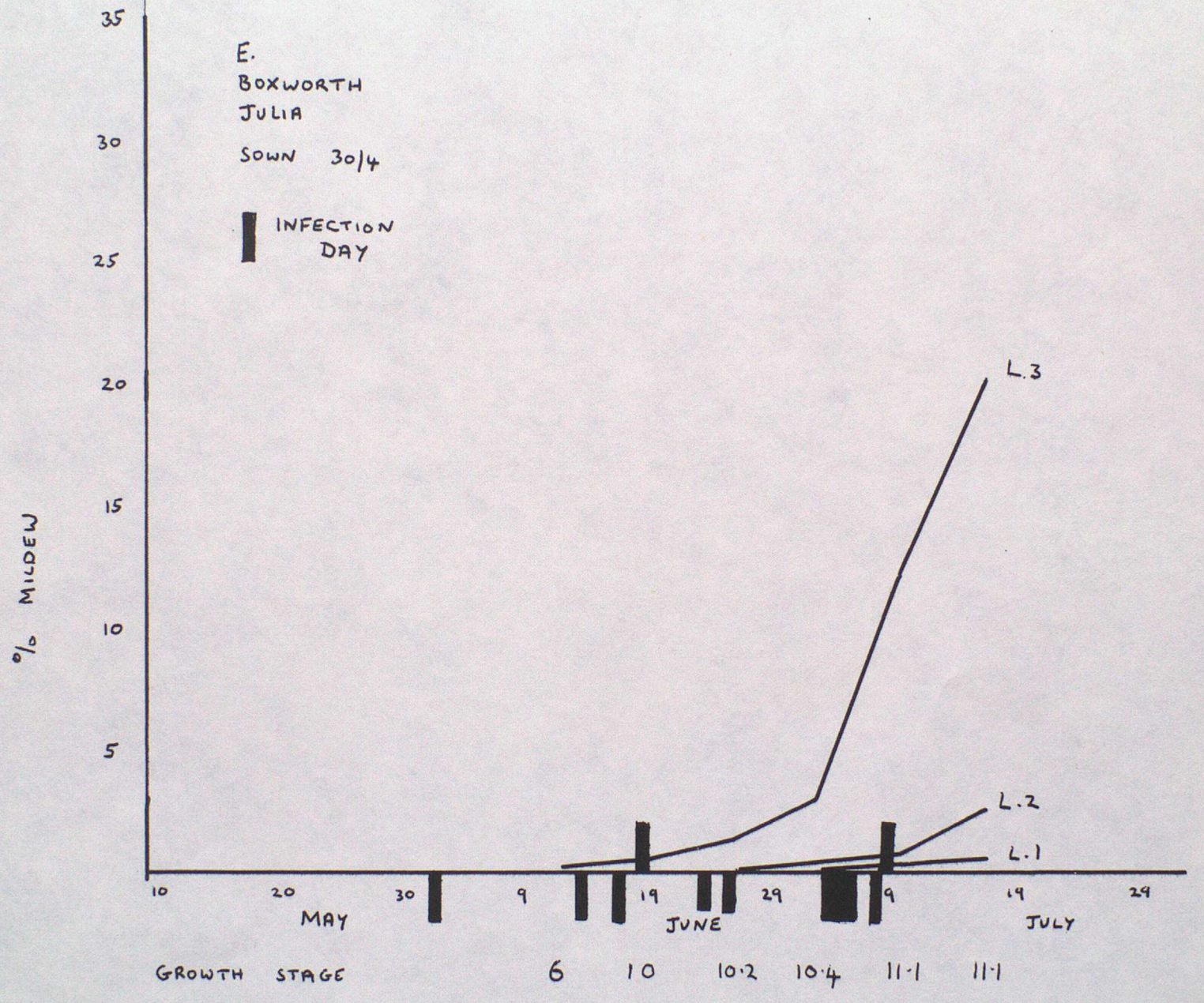

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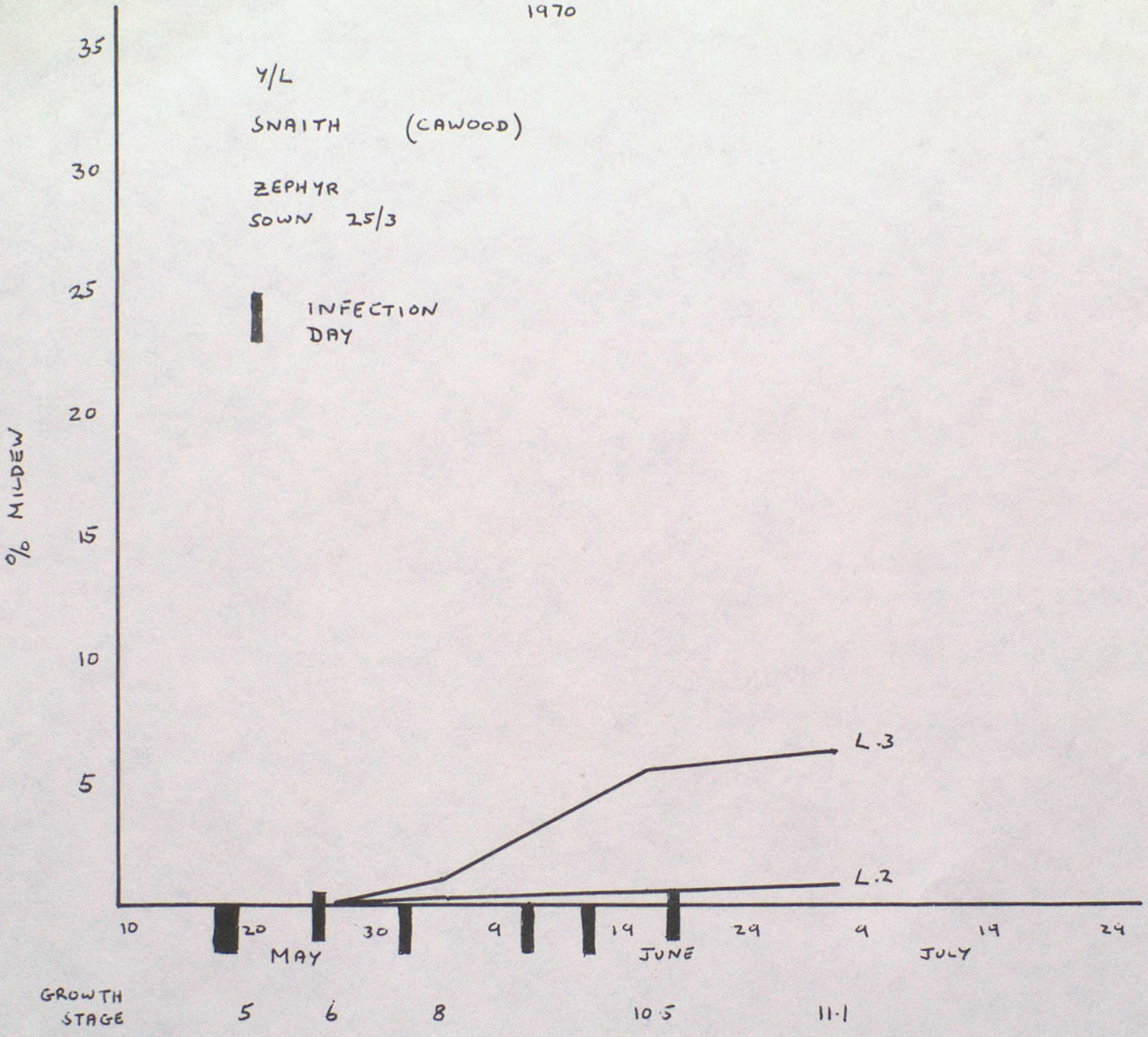

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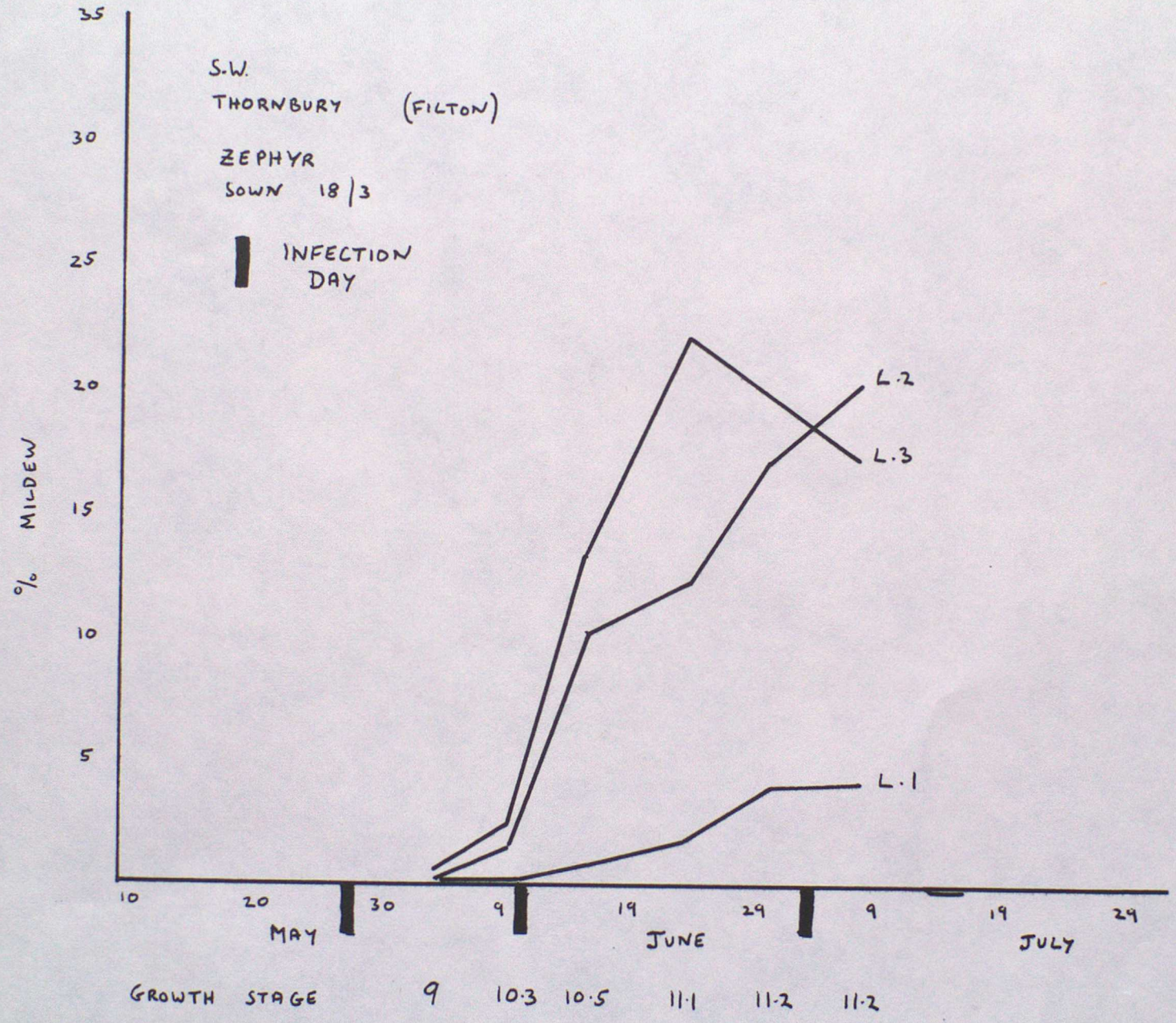

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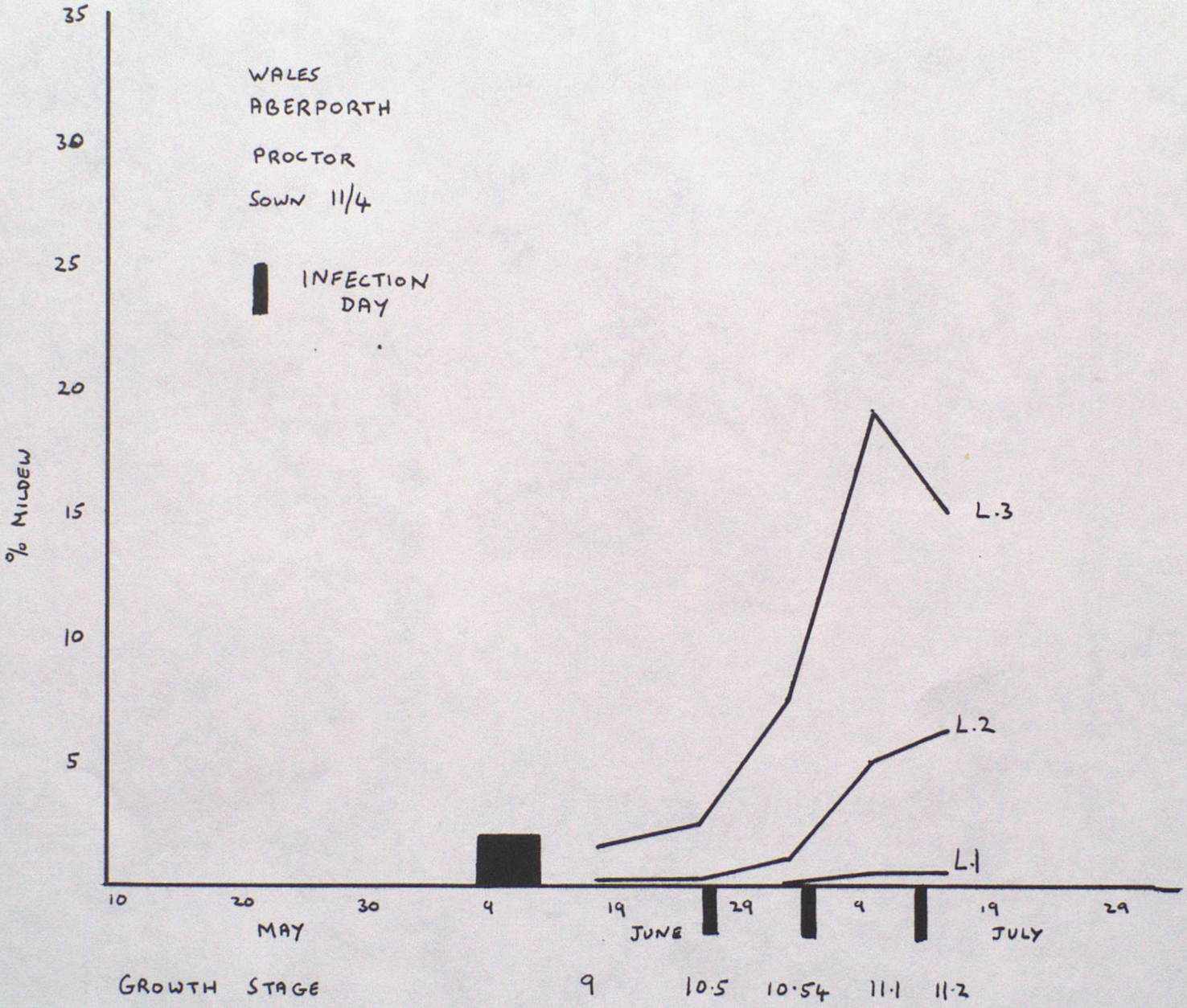

GROWTH STAGE 9 10·5 10·54 11·1 11·2

BARLEY MILDEW PROGRESS CURVES

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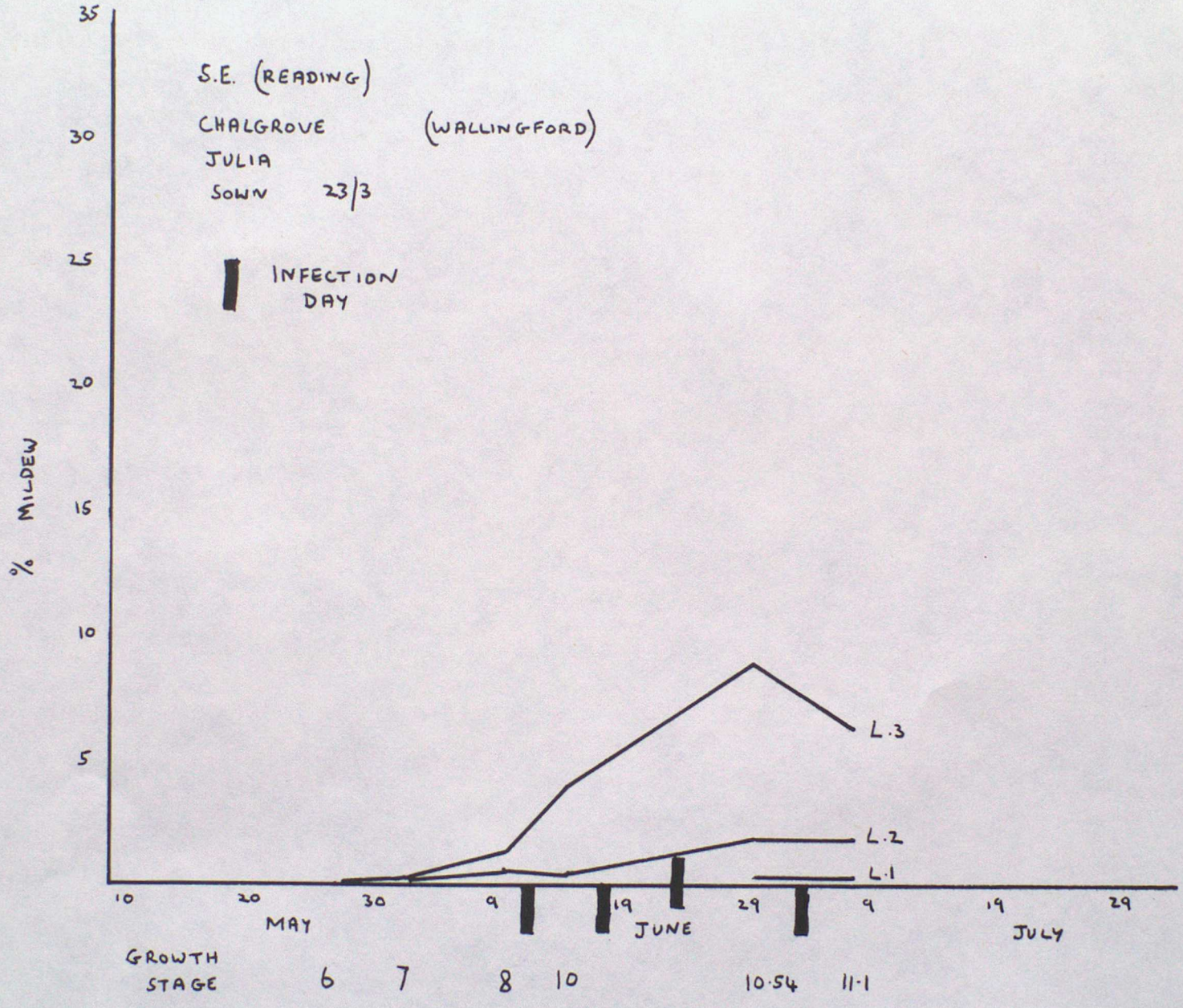

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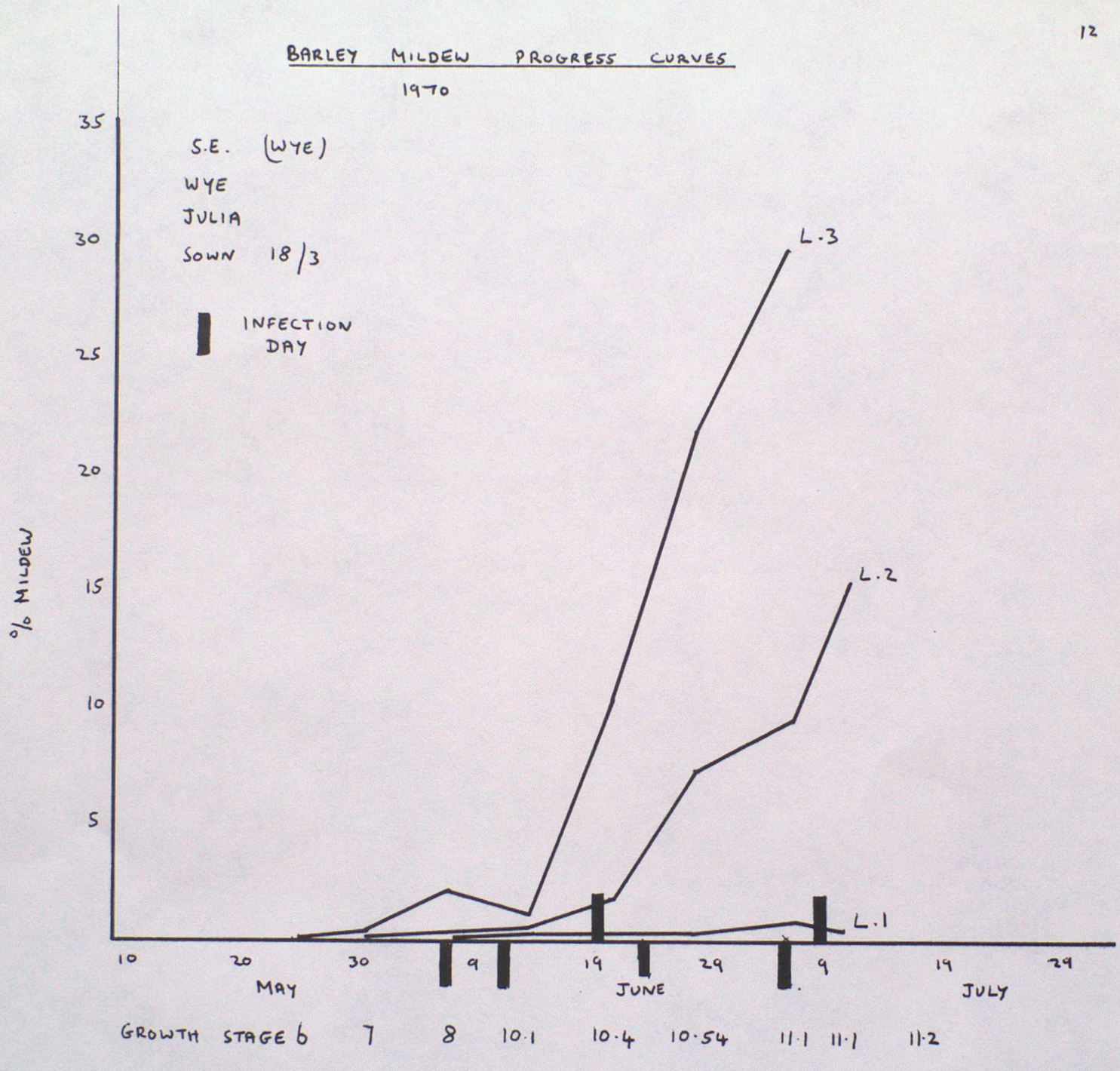

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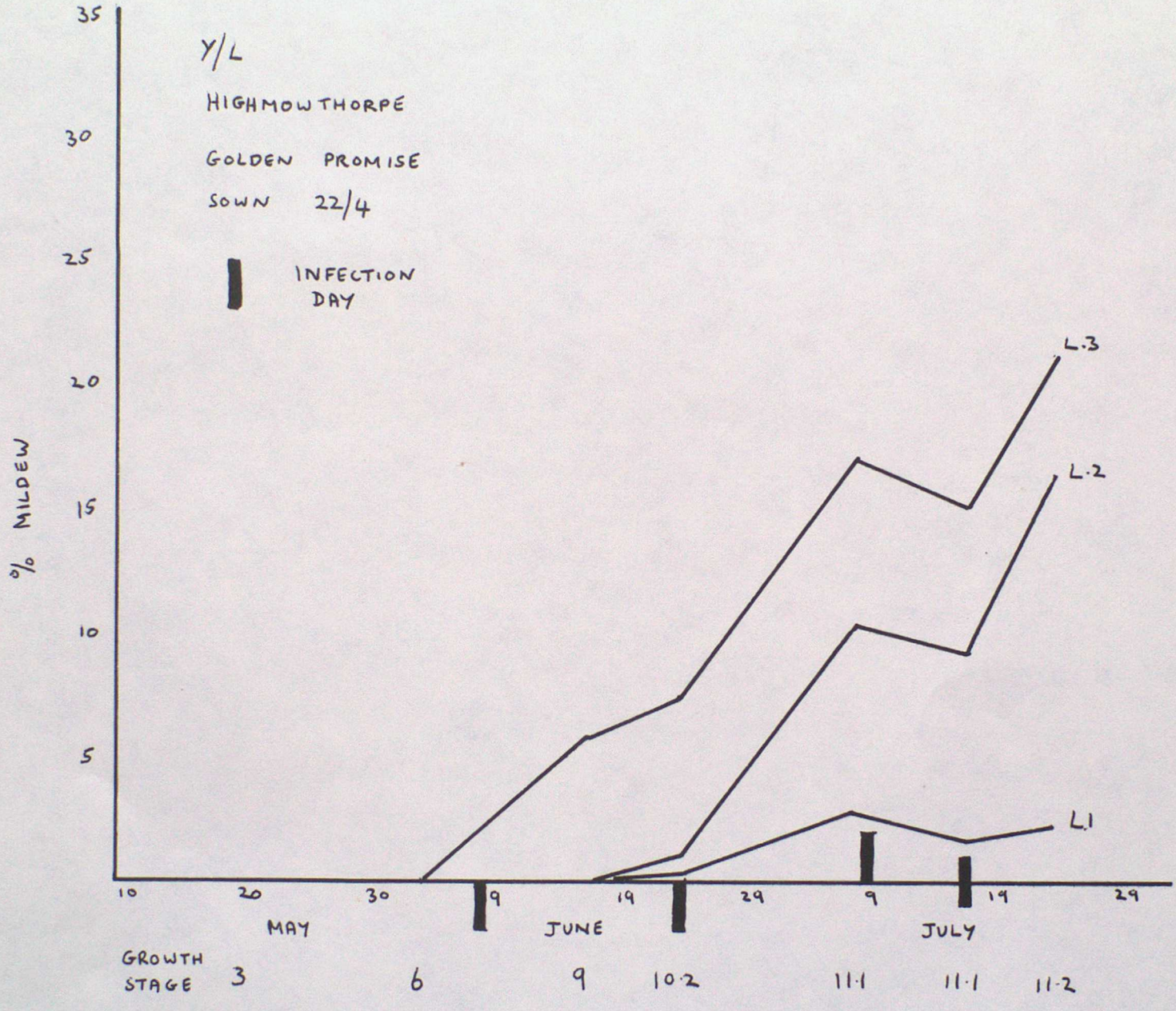

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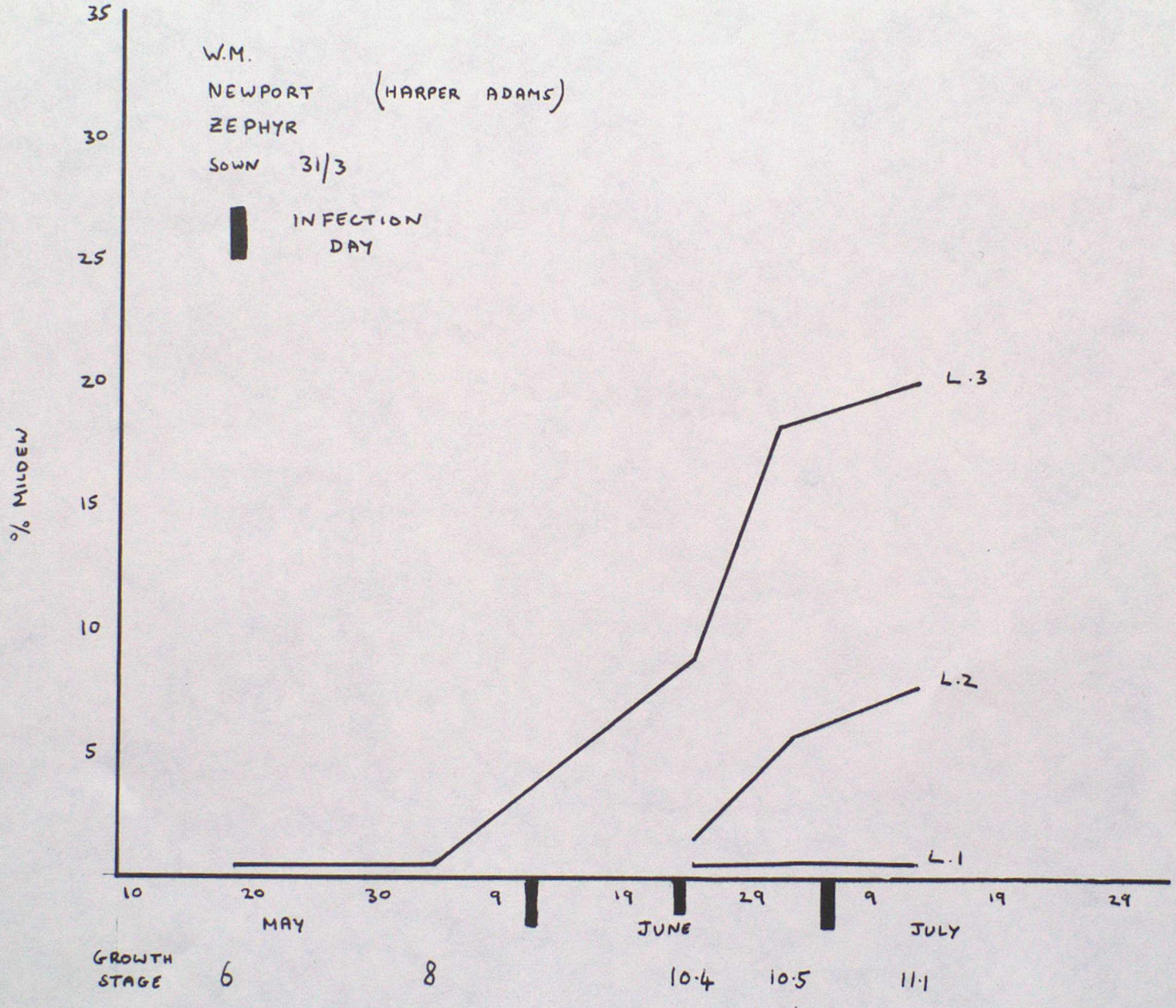

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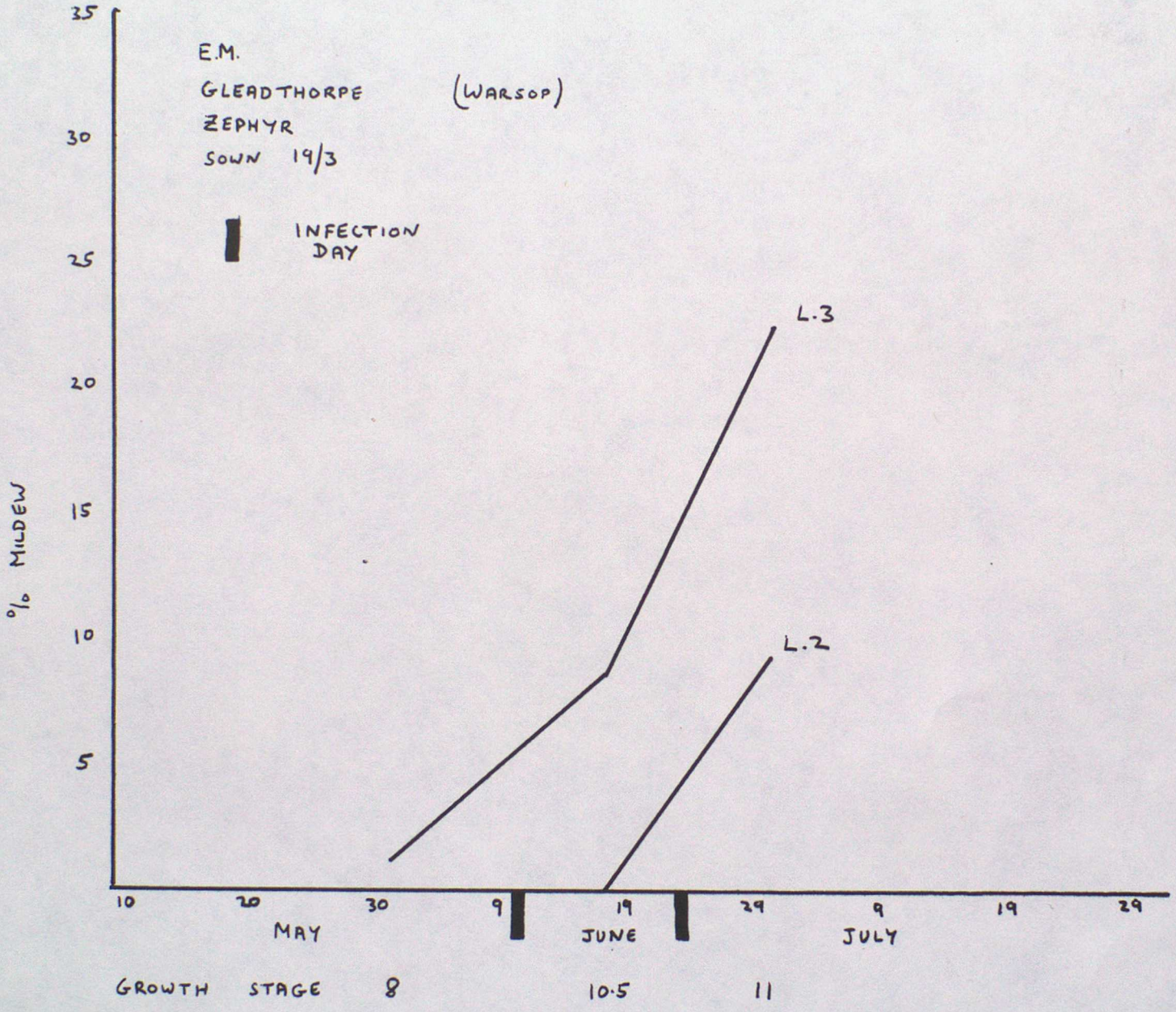

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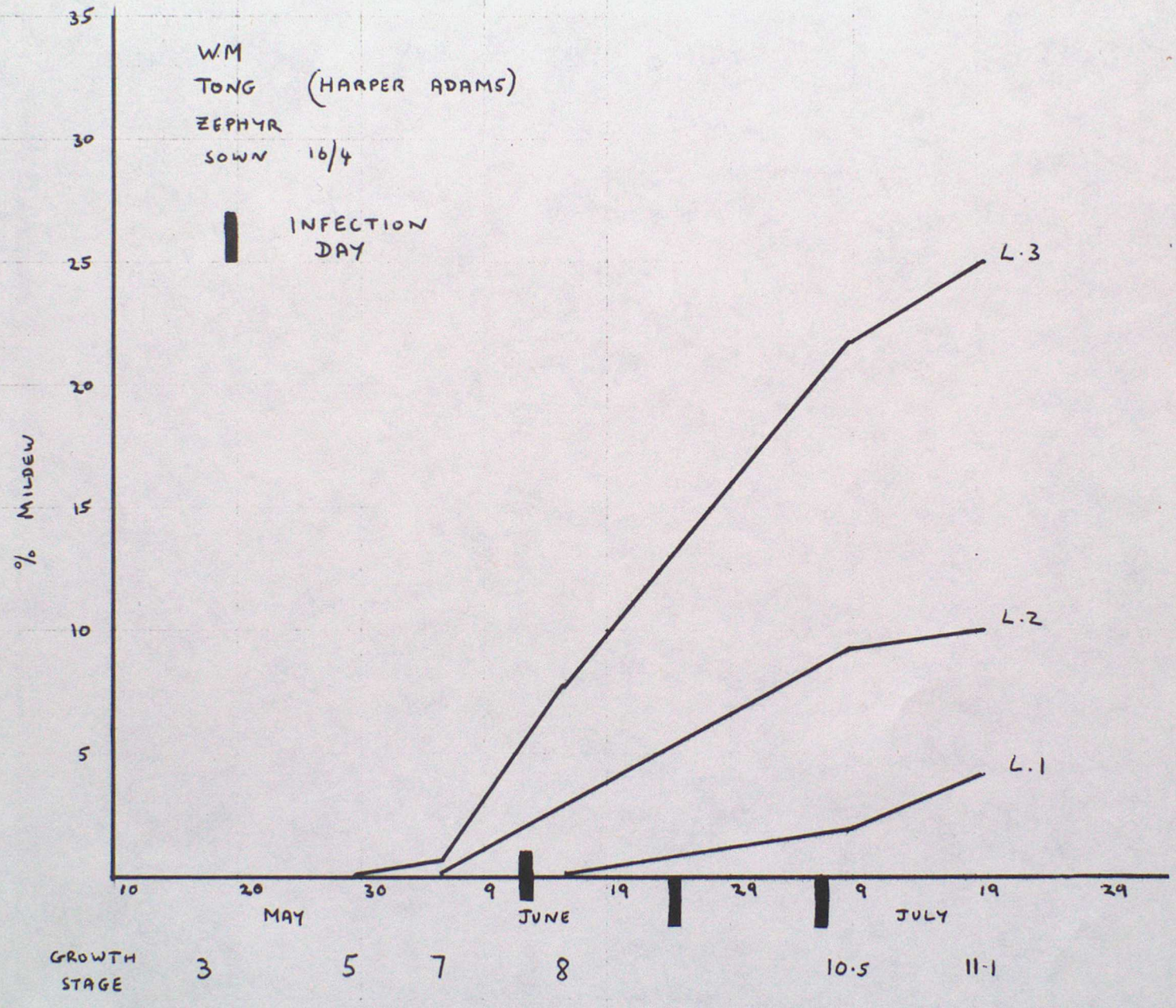

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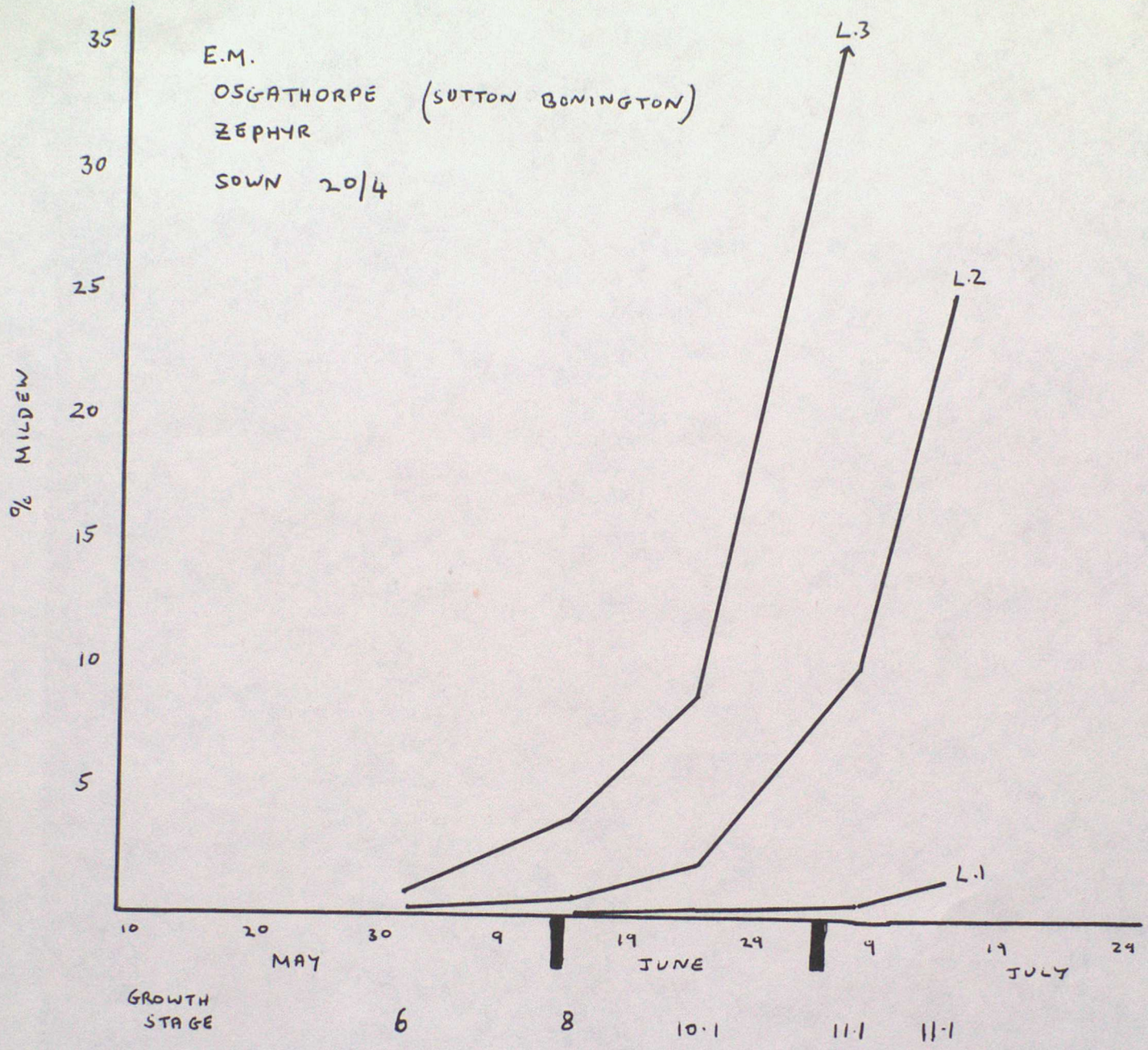

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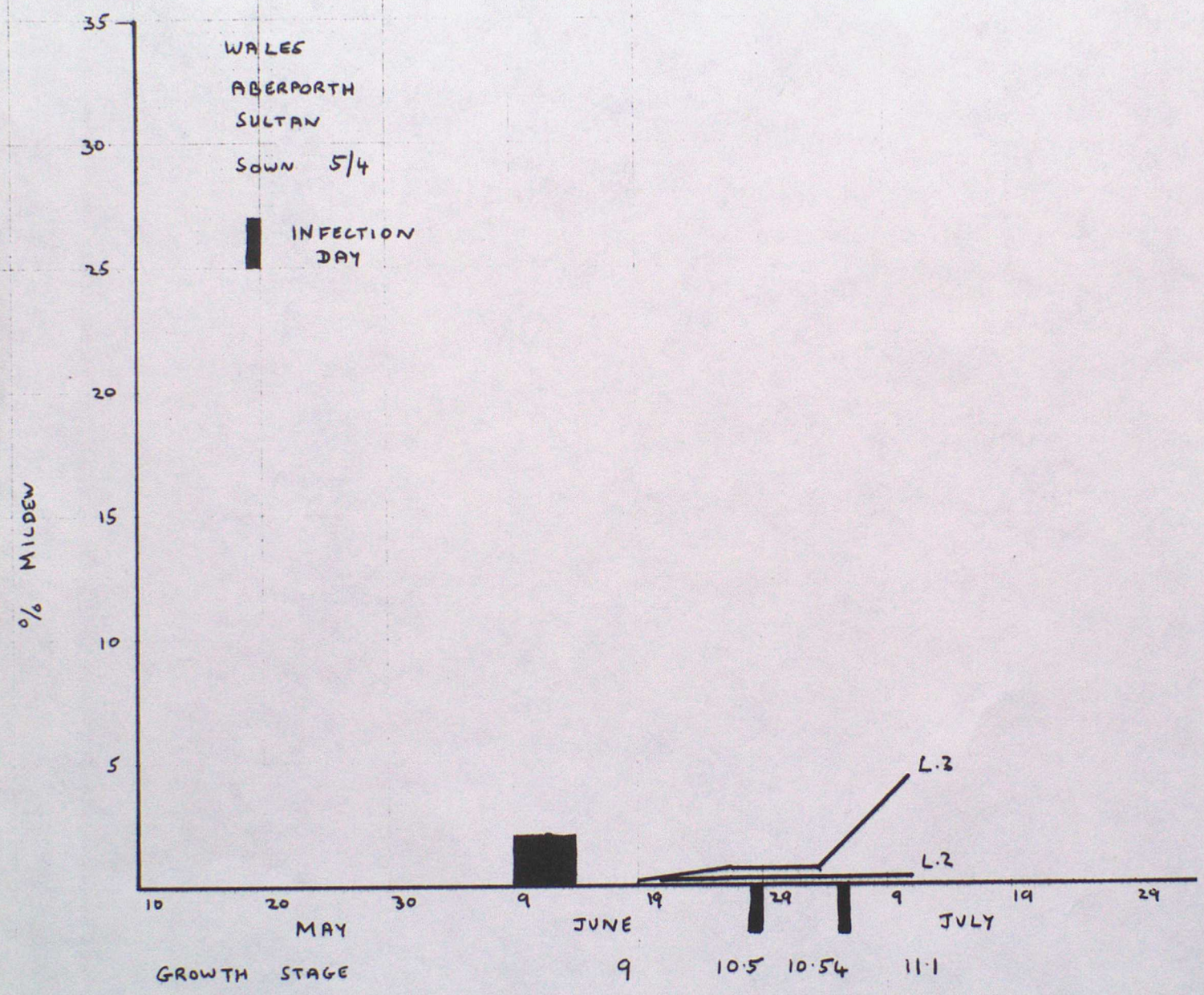

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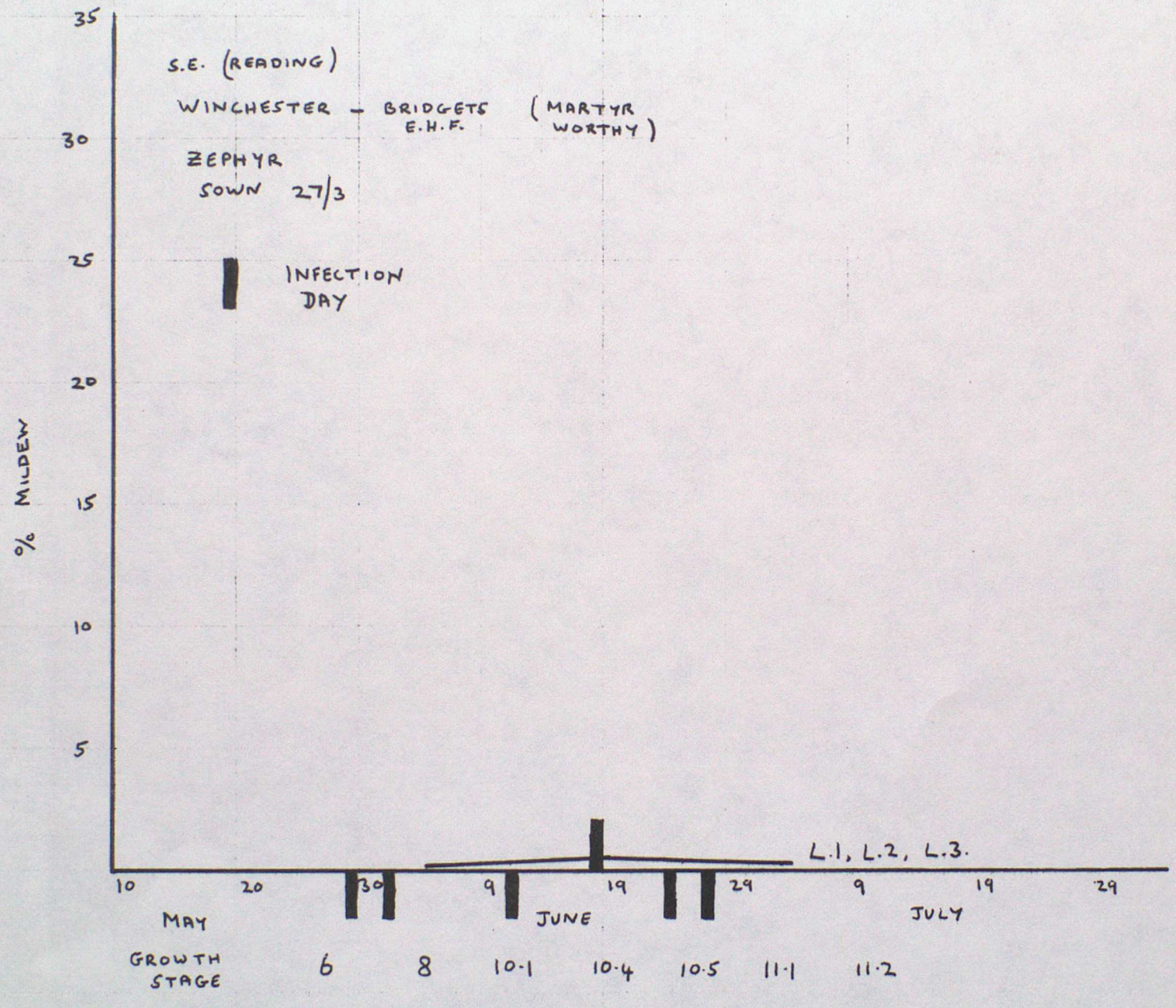

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